Puccinellia (Poaceae) in Western Australia

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Abstract

Williams, A.R. *Puccinellia* (Poaceae) in Western Australia. *Nuytsia* 16(2): 435–467 (2007). Two new native species, *Puccinellia longior* and *P. vassica*, have been identified from Western Australia. *P. longior* is restricted to the outer edges of salt lakes and salt-affected pasture land along the lower western margin of the southwest wheatbelt region in WA, and has also been collected from a saline wetland reserve in southeast South Australia. *P. vassica* is endemic to the outer edges of marine saltmarsh in reserved areas of the Leschenault Inlet near Bunbury. It was previously known from the nearby Vasse-Wonnerup saltmarsh near Busselton but is now extinct there because engineering works have reduced the marine influence in the estuary. It may be on the verge of extinction in the Leschenault Inlet also because (a) it lives on the outer edge of the high tide influence and is thus prone to weed invasion from non-saline areas, (b) its culms disintegrate almost entirely each year so it provides little resistance to competition, and (c) it has a low recruitment rate, with only a few scattered plants surviving at each site. The most common species is *Puccinellia stricta*, which occurs on the margins of salt lakes and salt-affected pastoral land throughout the southwest wheatbelt region, from Hutt River in the north to the Esperance region in the east. WA collections of this species differ from those elsewhere in southern Australasia, but in a continuous way that did not easily yield taxonomic distinction. The main source of variation is probably that the WA habitats all have to endure long summer drought each year. The agriculturally introduced Middle-Eastern species *P. ciliata* is well naturalized in saline lands in southwest WA, and a single collection of the introduced *P. gigantea* is recorded. Other introduced species appear to have not survived.

Introduction

Puccinellia Parl. (Poaceae) is a cosmopolitan genus of more than 90 salt-tolerant species that occur from the Canadian Arctic islands in the northern hemisphere to the sub-Antarctic Macquarie Island in the southern hemisphere. Amongst its Asian members, *P. tenuiflora* Scribner & Merr. was recently chosen as a model organism for studying the molecular biology of salt tolerance for use in bioengineering of monocotyledonous plants (Wang *et al.*, 2006), and some experimental progress has already been made (Soumin *et al.*, 2004). There may thus be some potential for application of this research to our Australian conditions through our native *Puccinellia* species.

When this study began in 2003 only one native species was recorded from Australia, together with three introduced species. Edgar (1996) provided a review of *Puccinellia* in New Zealand and offshore islands and this was the only available in-depth treatment of the genus in the Australasian region. Recent Australian Flora treatments included Walsh & Entwisle (1994), Jacobs & McClay (1993) and Jessop and

Toelken (1986), and South African grasses had been described by Gibbs Russell *et al.* (1990). Walsh (1991) published a note and a new name needed for the *Flora of Victoria*, and Weiller (N. Walsh pers. comm.) had prepared a draft report on the genus for volume 44A of the *Flora of Australia*.

Puccinellia species are generally restricted to the margins of saline wetlands or to salt-affected lowlands. In Western Australia the genus is restricted to the southwest, principally the inland agricultural zone. A wide range of *Puccinellia* collections was introduced to Western Australia from the Middle East in the 1950s, 60s and 70s by agricultural authorities, to ameliorate salt-affected land. The purpose of this present work was to establish the status of the native species in WA, in association with the Biological Survey of the Wheatbelt (Keighery *et al.* 2004) a part of the State-sponsored Salinity Action Plan, and to confirm the identity of the introduced collections at PERTH, many of which were identified only to genus.

Taxonomic History of *Puccinellia* in Western Australian

In Gardner's *Flora of Western Australia – Gramineae* (1952) just one species of *Puccinellia* was recorded, the native *P. stricta*. It was originally described by Hooker (1853) as *Glyceria stricta*. The lectotype (Allan & Jansen, 1939) is *Gunn* 1463 from a (salt) marsh at Launceston, Tasmania, held at K (sheet K000348683 carries the site and collector details and sheet K000348684 carries the illustrations for *Glyceria stricta* that appeared in Hooker's *Flora of Tasmania*, 1860). The species was transferred to *Puccinellia* by Blom (1930). It was the only native species recorded from Australia when this study began, and was also the most widespread species within the genus in both Australia and New Zealand. However, the specimen used by Gardner to illustrate his 1952 *Flora* (Plate XXVIIIB) has now been assigned to a new native species endemic to the southwest of WA, *P. vassica* A.R.Williams.

Steudel (1854), almost contemporaneously with Hooker's publication, described *Glyceria tenuispica* Steud. from a Drummond collection (V, 347) from WA. In Mueller (1872–1874), *G. tenuispica* is included, along with Mueller's earlier *Poa syrtica* and Hooker's *Glyceria stricta*, in the synonymy of *Festuca syrtica*. Bentham (1878) reasserted the priority of *G. stricta* and included Mueller's two names as synonyms, while *G. tenuispica* is also mentioned, not in synonymy, but in a note on the distribution of *G. stricta*. The single Gardner specimen at PERTH from Busselton was annotated by Hubbard in 1937 suggesting that it might be *Glyceria tenuispica*. I can find no other references to *G. tenuispica* in published literature. A specimen at MEL of *Drummond* 347 carries an undated annotation in Mueller's handwriting '*Glyceria tenuispica* Steudel. [then underneath] *Festuca syrtica* FvM var. *patens*, W.A. Drum. 347.' The varietal name seems not to have been published by Mueller. The Kew sheet of *Drummond* V, 347 (K000347908, high resolution image seen) carries a note from P. Jansen identifying it as '*Puccinellia stricta* var. *tenuispica*,' a combination which Jansen apparently never published. Both the MEL and K specimens of *Drummond* 347 fit *P. stricta* and in the analysis that follows I have included *G. tenuispica* as a synonym of that name.

Two varieties of *P. stricta* have been recognized in Australia (Walsh 1991) – var. *perlaxa* (from Victoria) and var. *stricta*, and three infraspecific taxa have been recognized in New Zealand (Allan & Jansen 1935) – var. *suborbicularis*, forma *luxurians* and forma *pumila*. However Edgar (1996) found that the species in New Zealand was so variable that it was not possible to delimit subgroups within it and left open the question of whether the Australian and New Zealand populations were taxonomically distinct. Hooker (1853) examined specimens from New Zealand and Tasmania and said of the latter "they are much larger than the New Zealand ones but not otherwise different".

Only one alien species, *P. ciliata,* had been recorded as naturalized in Western Australia but this and two others, *P. distans* and *P. fasciculata,* had been recorded as naturalized in the eastern states. All of these were probably the result of deliberate introductions. In 1951 Miles and Donald brought seed of a salt-tolerant species from Turkey and planted it at the CSIRO field station at Kojonup (WA) with a view to using it in reclamation of salt-damaged farming land. This species—presumably, as it was cited by Tan (1985) as having come from Australia and having been widely used in Western Australia for reclamation of saline areas—was originally identified as *P. capillaris* (Liljebl.) Jansen. A later collection of the material grown at Kojonup was determined by Bor (1968) to be a new species – *P. ciliata* Bor. Note that Bor (1968) cited the type specimen of *P. ciliata* as coming from Turkey but correspondence at PERTH shows that it came from the Turkish material cultivated at Kojonup. The details are given in Tan (1985).

The quest for reclaiming salt damaged land was then taken up by the WA Department of Agriculture. C.V. Malcolm and others collected salt-tolerant plants from many parts of the world in the 1960s and 70s. Malcolm *et al.* (1984) listed the following *Puccinellia* accessions (with the number of accessions, from various locations, in brackets): *Puccinellia airoides* (1), *P. capillaris* (1), *P. ciliata* (10), *P. distans* (10), *P. fasciculata* (2), *P. maritima* (4), *P. retroflexa* (1), *P. rupestris* (1), *P. stricta* (2) and *Puccinellia* sp. (72). Their accessions of *P. stricta* and *P. ciliata* were not introductions but were collected from sites in WA. All of their accessions labelled '*Puccinellia* sp.' were collected from sites in Turkey and Iran. Twenty-seven voucher specimens of the material from Turkey were lodged at the WA Herbarium. Amongst these voucher specimens, 22 were labelled *Puccinellia* sp. and of these I have determined 7 as *P. ciliata*, 12 as *P. distans*, 1 as *P. gigantea*, 1 as *P. grossheimiana*, and one was indeterminate because all the spikelets had fallen. Two of their voucher specimens were labelled *P. distans*, which I was able to confirm, and one was labelled *P. capillaris,* which I determined to be *P. ciliata*.

At the commencement of this study little was known about the distribution, abundance or conservation status of native *Puccinellia* in Western Australia, especially in light of the widespread planting of introduced taxa. However, recent collections were becoming available, especially as a result of the Wheatbelt Biological Survey (Keighery *et al.* 2004). Further collections were made as a result of preliminary findings of the study reported here.

Taxonomic Considerations

Puccinellia is widely regarded as a "difficult" genus. Some investigators recognize few species while others recognize numerous species. Davis (1983, 1988) studied phenotypic plasticity in the genus in order to identify the most useful kinds of morphological characters to use in taxonomy. He found that variation in both genotype and phenotype within the genus was "continuous in distribution and highly variable in magnitude". In an attempt to resolve this problem Choo *et al.* (1994) carried out a molecular study of a range of *Puccinellia* species from the northern hemisphere, together with representatives of the related genera *Phippsia*, *Sclerochloa* and *Catabrosa*. Their conclusions were that:

- *Puccinellia* was resolved as monophyletic,
- *Puccinellia, Phippsia*, *Sclerochloa* and *Catabrosa* are all genetically distinct genera,
- only two species groups were resolved within *Puccinellia*, each supported by only one character (i.e. most of the species were not distinguishable using the molecular characters studied),
- North American and Eurasian species of *Puccinellia* were not clearly separated,
- only 2 of the 21 *Puccinellia* accessions in the study were diploid, 19 were polyploid; the 2 diploid species were thought not to have been the full ancestors of the polyploids,

- "if additional data support the present resolution, or one much like it, major portions of the genus, distributed widely across both northern continents, might best be regarded as one or a few complexes of barely differentiated species, or perhaps as a mosaic of polymorphisms within which any species delimitations would be artificial" (p. 125).

Consaul & Gillespie (2001) studied diagnostic characters in Canadian Arctic Island *Puccinellia* species. Amongst 10 named species they were able to clearly distinguish 6 species or species aggregates but their multivariate study showed an "almost complete lack of distantly separated groups [which] revealed the quantitative morphological similarities and overlap amongst [all] the species" (p.950).

When these observations were added to those recorded above by Edgar (1996) for *P. stricta* it seemed wise to adopt a broad, rather than narrow, view of taxonomic delineations within the genus.

Methods

Useful Characters from the world literature

Different character suites appear to be useful in different floras. To identify the material from Turkey as well as that in Australasia, I compiled a list of species, characters and character states from the keys used by Tan (1985) and Davis et al. (1988) in Turkey, and Jessop & Toelken (1986) and Simon (1993) in Australia, with additional data taken from Hubbard (1984) and Walsh & Entwisle (1994). These characters were scored as a DELTA dataset for all the species occurring in Turkey and in Australia, and the interactive computer program INTKEY (Dallwitz *et al.*, 2000) was used to identify specimens in the PERTH collection and loan specimens.

Useful characters from the Australasian collections

The character list resulting from the above study was found to give inadequate attention to the structure of the panicle, and the work of Vegetti and Anton (2000) on panicle structure suggested further characterisation was required.

Grass Panicle Morphology. Recent discoveries in developmental biology (Carroll 2005) show that genes do not generally operate alone but as part of large gene complexes, and they operate (only) by being switched on and off. These 'switches' are located on the DNA strand near to the gene they control. One gene may be involved in a dozen or more different stages during development and will have a separate switch for each stage. When a gene is switched on, it affects development from that point onwards, but not anything before that point. Thus, during panicle development, 'choices' made early will influence and perhaps preclude (or allow) certain later choices, but later choices will not affect earlier ones.

For example, if peduncles are short and the number of spikelets and/or the number of branches per node is large, then the angle they can assume in relation to the panicle axis is controlled by spikelet crowding rather than by an intrinsic property of the peduncle itself. It is only when peduncles are long that a choice of spreading angle is possible. On the other hand, if peduncles are long, then the number of spikelets per node and the number of branches per node have no influence on branching

angle and are then (only) independent characters. Exsertion of the panicle from the leaf sheath is also correlated with panicle branch angle because the wider branch angles can only be achieved in the exserted condition.

Swelling of pulvini (axillary glands) causes panicle branches to diverge from the erect position. In some collections, pulvini appear to be absent, but do appear later at seedfall and cause some branches to expand. But in other collections the pulvini are swollen and obvious before divergence occurs, so the two characters (presence of pulvini and panicle expansion) are not necessarily completely correlated.

The arrangement of spikelets along the panicle branches is quite complex and is not well characterised by the two states used in the literature 'branches naked in proximal half or third' or 'at least some branches bearing spikelets to the base.' Rather, the arrangements form distributions of various kinds, and indeed the lateral branches of the grass panicle are now thought to be independent flowering units (Vegetti and Anton 2000) so it may be misleading to think of the panicle as a single organ. This is consistent with the gene-switching concept in that once a lateral branch gene complex is switched on, it will affect only characters downstream on that branch alone.

According to Vegetti and Anton (2000), the ancestral grass inflorescence is a panicle consisting of a series of alternating lateral 'flowering units' and ending in a terminal flowering unit. The flowering unit consists of a main florescence (spikelet) plus co-florescences that include short paraclades (a branch ending in a single spikelet) and long paraclades (branches that branch again and then end in spikelets). The ancestral condition is thought to be alternating flowering units, so the quasi-whorled condition in *Puccinellia* would be a derived state produced by reduction in the length of segments of the main axis. This appears to be confirmed by a few rare cases where an aberrant panicle has disjunct branching, compared with the standard kind of branching for the genus where all branches at a node arise from approximately the same point on the main axis.

According to the Vegetti-Anton theory, each lateral branch is an independent flowering unit and should be individually scored for its characteristics. In practice, however, it is often difficult to see the structure of individual branches if the number of branches and/or the number of spikelets per node is large and the spikelets are densely crowded together. It seemed more reasonable to look for summary measures such as minimum, maximum and/or mode (the most commonly occurring value) at each node, and to describe the spikelet arrangement in terms of the shape of its distribution. The important variation in panicle morphology is most easily summarised in describing just the two lowest nodes, but to see these in the enclosed state, the panicle needs to be dissected out of its sheath (i.e. cut the culm just above the second leaf collar and slide the panicle *down* through the flag leaf sheath).

The following characters were thereby defined (the number of panicle characters was matched to the number of spikelet characters, to balance their relative contributions to the similarity measures in the numerical analyses):

- *Number of spikelets per node*; the branches all (usually) emerge from a single point on the main panicle axis (here called a 'node'), so this character was simply the total number of spikelets on all branches at that point. In rare cases, two groups of branches will emerge slightly disjunct; in this case the internode has not fully developed so I either sought another specimen, or used the next node up (if it was similar) or scored just one of the disjunct groups of branches.
- *Spikelet distribution laterally per node*; the mode (the peak of the spikelet distribution) can be *proximal* (most of the spikelets crowded near the main axis), *even* (similar numbers at different distances from the axis), or *distal* (long bare peduncles with spikelets mainly at or near the ends).

- *Peduncle length*; a peduncle is the stalk of an inflorescence and the traditional view is that the whole panicle is the grass infloresence, but according to Vegetti & Anton (2000) each lateral branch is an independent inflorescence, so the stalk of each lateral branch up to the point of the first subsequent branch point is here defined as a peduncle. These lengths at each node vary a lot and are hard to measure when crowded together so the minimum and maximum lengths at the two lowest nodes were used (the lowest node can differ greatly or only a little from the second node). Only the length from the main axis to the first branch point was used.

- *Lateral Branch length*; maximum length of all lateral branches (mean of the two lowest nodes).

- *Panicle shape* at anthesis included three states: *contracted* (branch angle 0–45°), *spreading* (some branches up to 90°) and *deflexed* (some branches up to 180°). The spreading characters can only be achieved in the exserted state, so the correlation noted earlier is implied in these states. However, the exserted/enclosed state was retained as a separate character to cover the uncorrelated combination—'exserted and contracted'.

- *Crowding of spikelets*. The estimated number of spikelets per millimetre in the proximal third of the lateral branches at each of the two lower nodes was used as an index of crowding in the quantitative analyses. It was calculated as $C = ND/B$, where N is the number of spikelets per node, D is a function of the distribution type (taking continuous values of 1/3 for an even distribution, 2/3 for a proximal distribution, and 1/6 for a distal distribution)[1], and B is the maximum branch length. In the DELTA key and descriptions (where the user cannot calculate the output of a function), a visual estimate of crowding was used—whether or not spikelets overlap one another on panicle branches or are crowded together near the node.

Spikelet Characters. Number of florets per spikelet can vary either a great deal or only a little, and vary with distance either up or down, within a single panicle. In the most variable cases the number increased up the panicle, and the terminal spikelet had as many as 10–12–14 florets while the lowest had only 2–5. Furthermore, in some species and/or specimens, the innermost spikelets in the lower panicle branches were undeveloped. In some specimens, the terminal floret in a spikelet was developed and either male or bisexual, but in other specimens the terminal floret was aborted. No taxonomic significance was attached to any of these variable conditions, and spikelets taken for dissection were selected from the middle of the panicle. Number of spikelets per floret was reported as found.

There was little useful variation in glume shapes in the WA species, but this became significant in comparison with exotic species. Lower lemma indumentation varied significantly from glabrous to ciliate, as did the callus. Palea keels were always scabrous in the upper third, but varied in the lower half, being either glabrous, scabrous or ciliate. Anther colour varied from creamy white (with a purple tinge in some species) to rusty brown.

Character Scoring. For the purposes of the numerical analyses, non-numerical characters (e.g. presence/absence) were treated as ordered multistate characters and given positive non-zero values so that intermediate conditions made numerical as well as botanical sense. For example, lemma nerves were scored as either 'prominent' or 'obscure' but sometimes different lemmas on the same plant might show both conditions, or some lemmas might have an intermediate condition. By scoring 'obscure' as 1, and 'prominent' as 2, then the intermediate condition could be given a value of 1.5, or other such fraction as might reflect the situation.

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[1] The actual formula used to obtain a continuous function was $C = N(4/(2^D))/B$.

Specimen selection. Since panicle shape at anthesis was identified as an important character, specimens for the Australasian numerical study were selected so that they were all at approximately the same stage of development and in sufficiently good condition that all relevant measurements could be made upon them. Where possible, only specimens determined by well-known authors were used. Four geographically isolated provinces were sampled across the range of *P. stricta*: Western Australia, eastern Australia, Tasmania, and New Zealand.

Multivariate Analyses

Multivariate analyses were carried out to check the consistency and accuracy of the data, and to assess relationships between specimens and taxa using all the available information rather than just depending upon the character by character analysis that results from the INTKEY procedure. Two complementary kinds of methods were used, cluster analysis (using both Ward's method and the Paired Group method), and ordination (using Principle Coordinate Analysis), both kinds implemented by the program PAST (v.0.78, 2002, http://palaeo-electronica.org/2001_1/past/main.htm).

In Principle Coordinate Analysis (PCoA), the items are represented as points in an n-dimensional space, where n is the number of characters. The distance between each item and every other item is thus the distance between their two points in the n-space. The PCoA method extracts a set of axes that represent the data more efficiently than the original character axes. The first two of these axes are then used to plot the points in two dimensions so that we can see what the major pattern in the data looks like. Similar items appear close to one another on the resulting two-dimensional plot, but it should be remembered that there is unrepresented variance also present in the data so two points that are close in two dimensions may be separate on the third or fourth dimensions.

A clustering algorithm is a convenient way of overcoming the problem of the unrepresented variance in the PCoA plots. In Ward's method, cluster membership is assessed by calculating the total sum of squared deviations between items and cluster means. The criterion for fusion is that it should produce the smallest possible increase in the residual sum of squares. To avoid the bias that would result from the different measurement scales used for different characters, the data were normalized before analysis so that all characters have the same variance (as a result, all the numbers range around a mean value of about 1). Normalization is not required for PCoA as it is inherently catered for in the method. In the Paired Group method, clusters are built from the bottom up by joining the most closely similar items; the distance matrix (calculated as Euclidean distance) is then recalculated so that the distance between clusters is the mean of the distances between all their members.

While neither ordination nor clustering can produce a 'best' representation of multivariate data, the two methods can be used in combination in such a way that each makes up for the shortcomings of the other. Ordination is good at showing the overall pattern of distant relationships in the data, but not the close relationships. On the other hand, clustering is good at showing close relationships, but not good at showing distant relationships. For example, all items are forced to join a cluster eventually so some items can end up clustered together simply because they do not resemble any other item even though they may differ greatly from each another.

The list of characters and their states is given in Table 1. The original specimen data are too voluminous to list here, but are lodged on a CD in Excel and in plain text format with the PERTH herbarium library (WALIB Accession No. 623367).

Type Specimens

Relevant loan specimens were requested and a variety of responses were received, ranging from actual specimens, to on-line images, to high resolution images on CD. Type specimens cited were seen unless otherwise indicated with 'n.v.', 'image seen', or 'high-resolution image seen.'

Species Descriptions

In 2003, the PERTH collection was comprehensively examined using a character set compiled from the literature cited earlier, brought together in a DELTA database. This process yielded a new

Table 1. Characters, states and units of measurement (in DELTA format) used in the multivariate study of native and introduced *Puccinellia* species in Australia. Measurements were made on dry specimens. Explanatory comments are in square brackets.

#1. Habit/
  1. caespitose/
  2. stoloniferous/
#2. Duration/
  1. annual/
  2. perennial/
#3. Culm height/
  mm/
#4. Leaf <below flag leaf> blade length/
  mm/
#5. Leaf <below flag leaf> blade <shape>/
  1. involute/
  2. more or less flat/
#6. <Leaf below flag leaf blade stiffness>/
  1. erect/
  2. flaccid/
#7. <Leaf below flag leaf blade> width/
  mm/ [measured as is on dried specimens]
#8. Ligule <on leaf below flag leaf> length/
  mm/
#9. Panicle shape/
  1. contracted at flowering time (may spread later)/ [<45°]
  2. spreading at flowering time/ [up to 90°]
  3. spreading, some branches deflexed/ [>90° to 180°]
#10. Panicle length/
  mm/
#11. Panicle branch surface/
  1. smooth (or almost so)/
  2. scabridulous/
#12. Panicle <in relation to flag leaf>/
  1. enclosed by flag leaf/
  2. exserted above flag leaf/
#13. Number of lower panicle branches per node/
#14. Spikelet distribution on lower panicle branches/
  1. crowded near the base of lateral branches/
  2. evenly spread/
  3. mainly at the ends of long bare peduncles/
#15. Spikelets per node (mean of lower two nodes)/
#16. Spikelets <crowding on panicle branches>/
  1. not overlapping one another on panicle branches/
  2. overlapping one another on panicle branches/
  3. crowded together near the nodes/
#17. Minimum peduncle length/
  mm/
#18. Maximum peduncle length/
  mm/
#19. Maximum branch length/
  mm/
#20. Spikelet length/
  mm/
#21. Number of florets per spikelet/
#22. Lower glume length/
  mm/
#23. Upper glume length/
  mm/
#24. Glume tips/
  1. entire/
  2. erose/
#25. Lemma tip <shape>/
  1. tapering/
  2. blunt/
#26. Lemma length/
  mm/
#27. Lemma nerves/
  1. obscure/
  2. prominent/
#28. Lemma midnerve <whether excurrent>/
  1. not extending to the margin/
  2. extending to the margin, sometimes excurrent/
#29. Lemma indumentum/
  1. glabrous/
  2. sparse hairs near base/
  3. ciliate/
#30. Palea length/
  mm/
#31. Palea indumentum/
  1. glabrous in lower half/
  2. scabrous or ciliate in lower half/
#32. Callus hairs/
  1. glabrous/
  2. ciliate/
#33. Anther length/
  mm/
#34. Anther colour/
  1. creamy white/
  2. creamy white with purple tinge/
  3. rusty brown/

species, *Puccinellia longior*, here described. Edgar (1996) had raised a question over the relationship between Australian and New Zealand populations of *P. stricta*, and the characterization of *P. longior* in its Australasian context seemed a good opportunity to address that question. Relevant loan specimens were acquired and a selection, as outlined earlier, was studied in depth using the revised character list given in Table 1, and the data were used in the multivariate analyses. After the analyses were all completed, the data from the specimens was used to re-structure the DELTA database to reflect just the material I had examined. The descriptions appearing below were generated from that database so they are all based on my observations and measurements, but having been compared with relevant literature values for potential anomalies (such as the one noted below for anther length in *P. distans*).

Results

Determinations amongst PERTH collections. In general, the exotic specimens fitted the key data (based on published information) quite well, with one exception. Amongst the twelve specimens from Turkey and the one from each of Algeria and Tunisia that are labelled *P. distans,* all had anther lengths in the range 1–1.5 mm, compared to the literature values of 0.5–1mm. When this anomaly first appeared, I excluded anther length from the INTKEY determinations but found that the specimens still keyed out to *P. distans* on the other characters. Since this was the only character that separated this material from *P. distans*, and no other candidate name was obvious, I chose to expand the anther length range of *P. distans* up to 1.5 mm long. In reviewing this decision at the end of the study, I noted that anther length was a very important character in the genus generally, and further inquiry was warranted.

Table 2. Identification of PERTH collections.

Species	WA	Other Aust.	Turkey	Other
**P. ciliata*	17		7	
**P. distans*		NSW (2)	12	Algeria (1), Tunisia (1)
**P. fasciculata*		SA (1)		
**P. gigantea*	1		1	
**P. maritima*				UK (1)
**P. grossheimiana*			1	
P. stricta	27	Victoria (1)		
P. longior sp. nov.	7			
P. vassica sp. nov.	7			
P. perlaxa		NSW (1)		

A study of the frequency of anther length over all the data in the study showed a distinct bi-modal distribution, with the first mode at 0.7 mm, and the second at 1.5 mm. This could perhaps reflect an underlying mechanism that, on average, doubles the time that the anther growth gene complex is switched on during embryonic development, or perhaps a gene duplication or polyploid event that doubles the amount of growth promoter produced. I examined further specimens of *P. distans* from England, Sweden and New Zealand, and found that these all had anther lengths in the literature range of 0.7–1.0 mm. I then did a multivariate analysis on all the specimen data together. Both cluster methods linked up all the *P. distans* specimens together, separate from any other grouping, but closest in each case to *P. fasiculata*. I conclude that *P. distans* was introduced to WA from the Middle East, but the specimens varied from the standard description in having longer than usual anthers. But since none of this introduced material appears to have survived in the field, I have retained the literature values for *P. distans* anther length at 0.7–1.0 mm.

Table 3. Identification of the Middle Eastern voucher material at PERTH.

Williams names	Malcolm names		
	Puccinellia sp.	*P. distans*	*P. capillaris*
Puccinellia sp.	1 (no spikelets)		
P. ciliata	8		1
P. distans	14	2	
P. gigantea	1		
P. grossheimiana	1		

Amongst the vouchered introduced species, *P. ciliata* has successfully naturalized in WA, but *P. distans* and *P. grossheimiana* have failed to naturalize.

Amongst the field collections of native or apparently naturalised material from Western Australia, *P. gigantea* was a new (single) record for the State, and two new native species *P. longior* and *P. vassica* were discovered. The multivariate analyses described in the Methods section were used to characterize these new taxa within the Australasian context and to decide upon their rank.

Multivariate analyses

Western Australian Collections. The results for the PCoA method, using all characters but just the Western Australian native collections, are shown in Figure 1. The three closest-knit groups produced by Ward's method of clustering are outlined. There is a clear separation between all the members of the groups labelled *longior* and *vassica* from the main body of the *P. stricta* collections. The ranks of these taxa were assessed as follows.

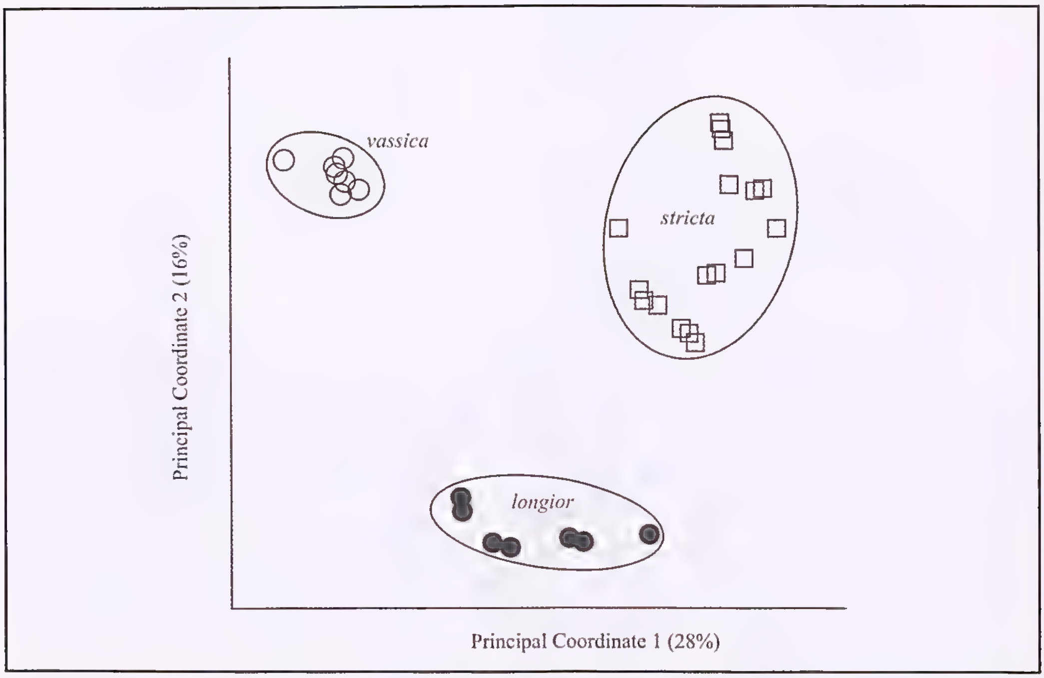

Figure 1. Principal Coordinate Analysis plot of Western Australian native specimens of *Puccinellia* using all the character data as listed in Table 1. Both clustering methods produced the same three groups (outlined), which consist of two new species, *P. longior* and *P. vassica*, and the Australia-wide *P. stricta*. The percentage variation accounted for by each coordinate is given in brackets.

Puccinellia longior displays its claim to species rank with very distinctive morphological features, but it also has a distinctive geographical distribution. The major morphological distinctions are in the anthers and ligules. The anthers are long (1.1–1.7 mm compared with 0.5–0.9 mm in *P. stricta*), linear and rusty brown coloured (both before and after dehiscence) compared with ovate and creamy white in *P. stricta* (before and after dehiscence). The ligules are consistently and considerably longer than in *P. stricta* (3.3–4.8 mm compared with 1.0–2.3 mm). Inspection of the species descriptions shows that *P. longior* is larger than *P. stricta* in many aspects in WA, and is comparable in size to the largest specimens of *P. stricta* from elsewhere in Australasia.

The very narrow east-west distribution of *P. longior* follows the line of drainage transition between ancient drainage surface inland and rejuvenated drainage surfaces along the west and south coast, as shown in Figure 2. This is quite remarkable given that *P. stricta* occurs throughout the whole wheatbelt region. The restricted distribution of *P. longior* to this southern drainage corridor may mean that it is only mildly tolerant of salt and grows only in areas that are flushed with flowing surface water during the winter wet season. In view of the rising salt levels in this area the species could thus be at risk of extinction.

Puccinellia vassica. A distinctive specimen of *Puccinellia* was collected from Busselton by Pries in 1870, and another of the same taxon by Gardner in 1936. Gardner used his specimen to illustrate *P. stricta* in his 1954 *Flora of WA* Vol. 1 Gramineae, Plate XXVIIIB. However, no further *Puccinellia* collections have ever been made from the Busselton area, and nothing quite like the Busselton collections has subsequently been collected from anywhere else in WA.

Unfortunately, no site data was given for either of these specimens, but the most likely saline habitat in that area was the marine salt marshes of the Vasse-Wonnerup inlet along the coast. *Puccinellia stricta* is widespread across Australasia, and occurs around salt lakes right through the WA wheatbelt, but there are no salt lakes in the Busselton area. Drummond's collection 219 from Western Australia, lodged at MEL (likewise with no site data given), also matched the Busselton collections and very likely came from that area also.

A search of the area was therefore carried out in November 2005 but all such sites in the Vasse-Wonnerup wetlands were heavily weed-infested and/or converted to pasture as a result of floodgates having been installed to mitigate seawater inflow during the dry summers (Brearley 2005, Ch. 4). However, north of Busselton, we found a few similar specimens, sparsely distributed, at small sites in Bunbury and in two reserved areas of the Leschenault Inlet. According to Figure 1, these seven specimens are all uniquely similar to one another and quite different to the other native *Puccinellia* specimens in WA.

The distinctive characteristics of the group include a long ligule (2.5–5 mm, compared with 1–2.3 mm for *P. stricta* var. *stricta*), glabrous lemmas and callus, paleas glabrous for most of their length and only having a scabrous upper quarter. Spikelets are very crowded on short glabrous peduncles, with a large number of spikelets per node. No other *Puccinellia* have been collected from marine salt marsh in WA, even though small areas of it exist around inlets and estuaries all around the south-west and south coast (see Brearley 2005). The combination of morphological and geographical distinctiveness clearly gives the taxon species rank.

Identification of *P. vassica* requires some comment on C.E. Hubbard's annotation '*Glyceria tenuispica*' on the Gardner specimen of 1936. As mentioned earlier, Steudel raised the name *Glyceria tenuispica* from Drummond collection V no. 347, a duplicate of which is at Kew, (K000347908).

Figure 2. Distribution of *Puccinellia longior* in relation to drainage systems in Southwest Western Australia.

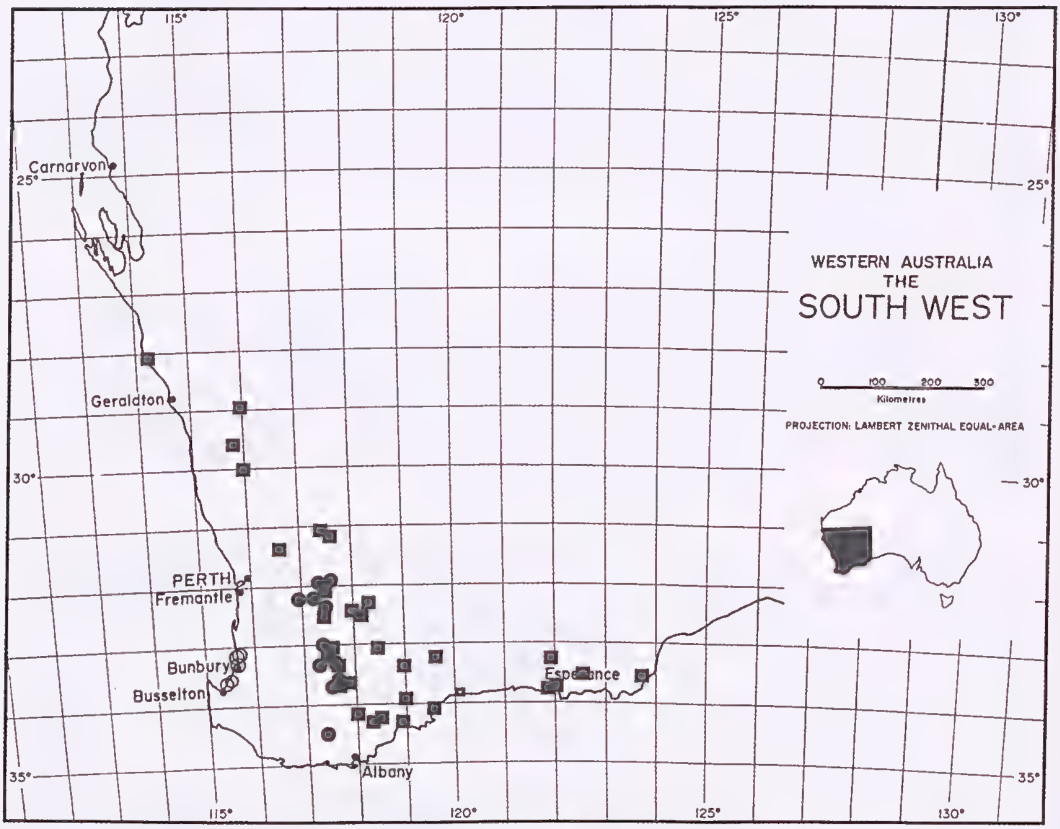

Figure 3. Distribution of *Puccinellia stricta* ■, *P. longior* ● and *P. vassica* O.

From a high resolution image of this sheet, I have determined it to be *Puccinellia stricta* var. *stricta*. Drummond collected it during his trip to the Stirling Range, Pallinup River, Mt Barren Range and Cape Riche area in 1849 and so it is likely that he found it on the margin of an inland salt lake, and not in the marine salt marshes of the Geographe coast where *P. vassica* occurs. Hubbard's note is thus now somewhat misleading. I have included *Glyceria tenuispica* as a synonym of *Puccinellia stricta* in the taxonomic section below.

The distributions of all three native taxa in WA are shown in Figure 3.

Australasian study of *Puccinellia stricta*

To answer the question of how *P. stricta* from WA compares with collections from elsewhere in Australasia, a selection of loan specimens from three other geographically separated regions (eastern Australian mainland, Tasmania, and New Zealand) were examined and the ordination plot is presented in Figure 4. Two well-separated groups were identified in the cluster analyses, and they show that the *P. stricta* var. *perlaxa* specimens are all quite unlike anything else. I showed this result to Neville Walsh, the author of *P. stricta* var. *perlaxa*, and he agreed that it clearly deserves species rank, so we have in this paper elevated it to *Puccinellia perlaxa* (N.G. Walsh) N.G.Walsh & A.R. Williams.

The *P. perlaxa* specimens were then removed from the *P. stricta* group, and the data re-analysed, this time using only spikelet and panicle characters to eliminate the environmental influence inherent

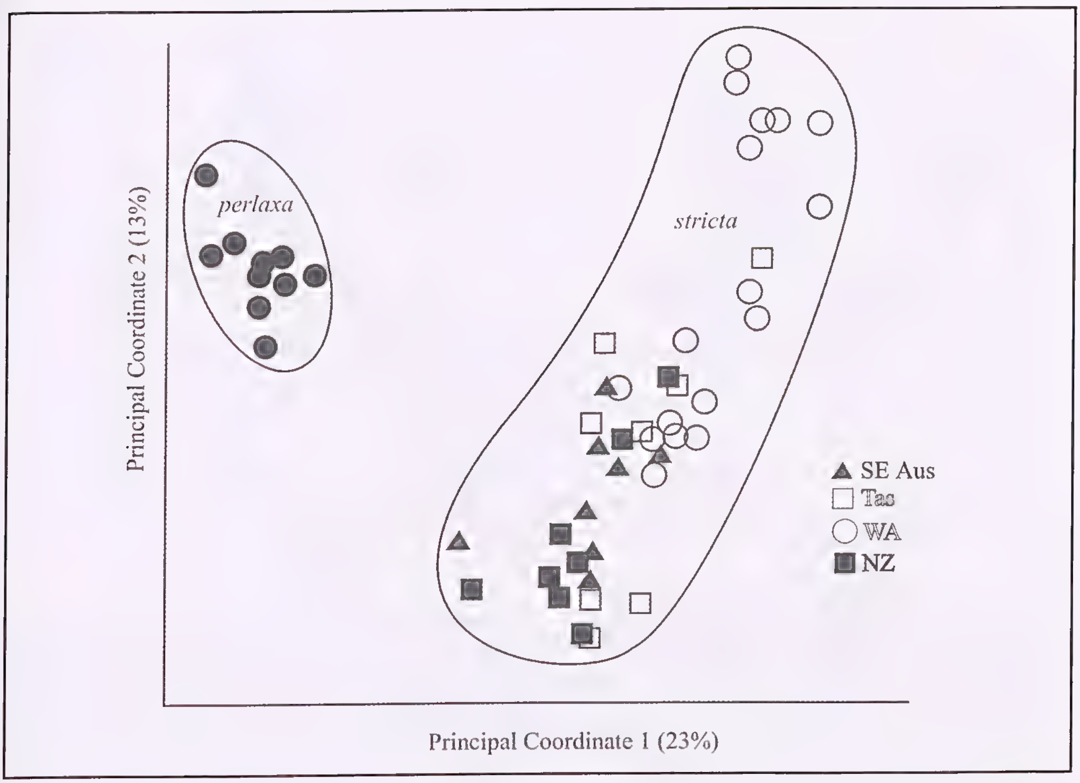

Figure 4. Principal Coordinate Analysis plot for *Puccinellia stricta* collections from across Australasia. Both cluster methods yielded the same two groups (enclosed by lines) separating *P. perlaxa* from all the others, thus supporting its elevation to species rank. The variation accounted for in each coordinate is given in brackets.

in the vegetative characters; the result is plotted in Figure 5. The collections are symbolized by region of origin, and the three type collections (Hooker's *Glyceria stricta, Gunn* 1463 from Tasmania, and Mueller's two 1847 collections of *Poa syrtica* from South Australia) are identified. There is a continuum of variation across these regions and no outstanding groupings were identified in the cluster analyses as in the previous cases. The WA material all segregates at one end of the plot, suggesting that they are somewhat different to other collections. The taxon descriptions given below were therefore separated into WA collections and 'south eastern Australia and New Zealand' (SEANZ) groups to show where the main variations occur. The WA collections are on average much smaller plants and this is most likely due to the generally drier environment—inland salt lakes and saline areas that are typically dry throughout the summer, compared with mostly coastal habitats elsewhere with generally wetter summers.

Edgar (1996) noted that *P. stricta* in New Zealand showed a wide range in character variation, notably the height of the plant and the shape of the panicle. Under extreme conditions the plants may become "very stunted", and Edgar quoted a height range of (2.5)–10–50–(65) cm which I have also observed. Edgar described the panicle to be "at first narrow linear, … at flowering … often still enclosed near the base, … later more open with ± spreading branches, .. usually completely free from the uppermost [leaf] sheath at maturity". Most of the WA collections had the panicle enclosed or closely subtended by the flag leaf sheath and only a few showed the later spreading at maturity and exsertion beyond the flag leaf.

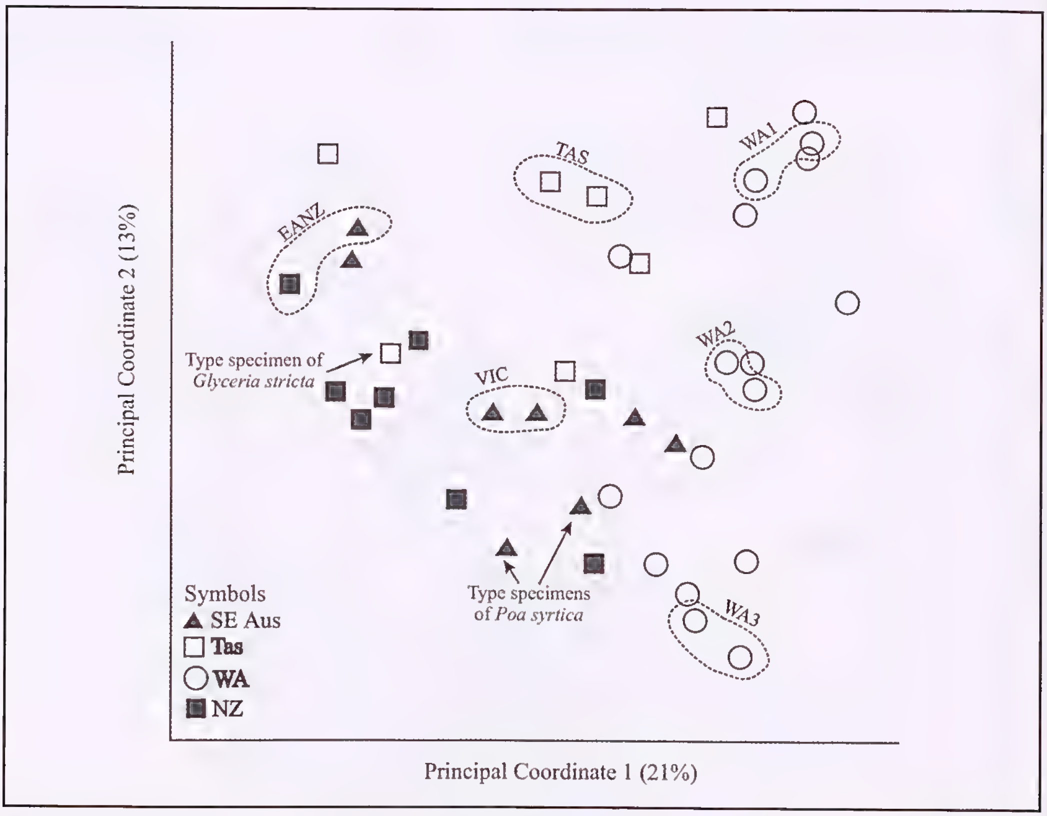

Figure 5. Principal Coordinate Analysis plot of *Puccinellia stricta* specimens from across Australasia, including three Type specimens. Only spikelet and panicle data were used, as listed in Table 1. There is a continuum of variation. Pairs of specimens that were the most closely clustered together are outlined and labelled, and their averaged character values are compared with those of the Type specimens in Table 4.

To illustrate the range of variation represented in Figure 5, the characteristics of the six most similar pairs of specimens (determined by both cluster analyses) are compared in Table 4 with the values for both Hooker's and Mueller's TYPE specimens and for the 'Species A' characteristics suggested in an earlier draft treatment of *Puccinellia* in Australia (Sharp & Simon 2002).

Table 4. Important characters amongst specimen groups (identified in Figure 5) from across the Australasian range of variation in *Puccinellia stricta.* Type 1 from Hooker's specimen, Type 2 from Mueller's specimens, and Species A was a suggested subgroup in earlier work. Bold entries are statistically significantly different from the median of the nine (or eight) groups.

	Specimen Groups								
Characters	**WA1**	**WA2**	**WA3**	**EANZ**	**VIC**	**TAS**	**TYPE 1**	**TYPE 2**	**Species A**
panicle exsertion	enclosed	enclosed	**exserted**	enclosed	enclosed	enclosed	enclosed	enclosed	enclosed
panicle shape	**open**	contracted	contracted	contracted	contracted	contracted	contracted	contracted	contracted
panicle length	88	63	44	**273**	120	75	125	112	150
spikelets per node	29	10	8	**38**	**42**	23	15	15	
branches per node	7	4	3	7	5	6	5	3	
ped. length min	1	1	1	**3**	2	2	1	1	
ped. length max	10	5	4	**29**	12	12	9	6	
branch length max.	33	26	12	**83**	53	40	35	23	
crowding index	**1.2**	0.5	0.7	0.5	0.8	0.6	0.4	0.6	
florets/spikelet	7	**10**	6	7	8	7	6	6	**9**
spikelet length	6.3	6.9	5.5	8.2	7.8	7.0	7.0	6.0	7.7
lower glume length	1.4	1.3	1.3	1.9	1.7	1.6	2.0	2.0	2.2
upper glume length	2.2	2.0	1.8	3.0	2.6	2.8	3.2	2.5	2.9
lemma nerves	**prominent**	**prominent**	obscure	obscure	obscure	**prominent**	obscure	obscure	**prominent**
lemma length	2.7	2.3	2.4	3.1	2.5	3.3	**3.6**	2.9	2.8
lemma indumentum	**v. hairy**	**hairy**	**hairy**	glabrous	**hairy**	**hairy**	glabrous	glabrous	**hairy**
palea length	2.5	2.2	2.2	**2.9**	2.4	2.6	3.0	2.3	2.4
anther length	0.7	0.7	0.7	0.8	0.7	**0.9**	**0.9**	0.7	0.8
leaf blade	**flat**	**flat**	rolled	rolled	rolled	rolled	rolled	rolled	rolled
leaf blade	**flaccid**	**flaccid**	stiff	stiff	stiff	stiff	stiff	stiff	stiff
blade width	**1.3**	1.0	0.7	0.9	0.8	0.6	0.6	0.7	**2.0**
blade length	108	40	40	**198**	118	68	75	117	100
ligule length	2.0	1.3	1.5	2.3	2.3	1.4	1.5	1.9	2.0
culm height	188	133	143	**650**	380	205	355	300	380
habit	annual	annual	annual	**perennial**	annual	**ann./per.**	annual	annual	annual

Significant deviations from the average values in Table 4 were determined using a median range test[2] and they are marked in bold. Mueller's Type specimens do not significantly deviate from the group average in any characters, while Hooker's Type specimen only deviates in minor ways. This suggests that indeed we are looking at a fairly Normally distributed suite of specimens relative to these Type specimens. On the other hand, every group differs from the average in two or more characters, so no group is exactly like the Type specimens. The EANZ group differs in 9 characters, the WA groups differ

[2] The median range test assumed that the values for each character were Normally distributed and that the confidence interval for the sample median was estimated by the range from the median to the nearest extreme value. This range was then applied towards the furthest extreme from the median, and any values outside this range were marked as significantly deviant.

in 2, 5 and 7 characters, the Victorian group differs in 2, and the Tasmanian group differs in 4 characters. The WA material is therefore not the most deviant amongst these groups.

WA1. This pair has panicles with one or more expanded branches, as well as some unexpanded branches having prominently swollen axillary glands (pulvini) suggesting that expansion may be imminent. The spikelets are crowded, and the lemmas have prominent nerves and hairs. The leaves tend to be flat and flaccid rather than involute and stiff.

WA2. This pair is similar to the previous, but with the standard contracted panicle, and smaller in nearly all size characters. They both come from seasonally dry inland saline lakes.

WA3. This pair is more similar to the Type specimens, deviating only in having an exserted panicle and hairy lemmas, but smallest of all in most dimensions, with very narrow panicles carrying fewest branches and spikelets per node. They both come from near-coastal saline lakes but at the two extremes of the north-south distribution of the species in WA—one from Utcha Spring nature reserve, just north of Hutt Lagoon in the north, and the other from Yellilup swamp near Bremer Bay in the south.

EANZ. This pair is the most deviant, being physically the largest in most dimensions, and perennial, coming from a higher rainfall region.

VIC. This pair is nearest of all to the Type specimens, differing only in having hairy rather than glabrous lemmas and more spikelets per node.

TAS. This pair is again very similar to the Type specimens, differing qualitatively in having hairy lemmas with prominent nerves, and one member was perennial.

Some WA and other Australian specimens of *Puccinellia* carry an annotation from C.M. Mihaich (now Weiller) '*Puccinellia* sp. aff. *stricta*.' These specimens were referred to an unnamed 'Species A' in Weiller's draft report on the genus in Australia (N. Walsh, pers. comm.) and she recommended further study, particularly of the WA material. The key characters suggested to distinguish it from *P. stricta* were 'lemma nerves prominent, lemma papillose, palea bidentate,' to which Neville Walsh added in an annotation to the draft 'lemma very broadly obtuse to nearly truncate, often bidentate or ruminate (c.f. lemma broadly acute to obtuse, mostly entire).'

Table 4 shows that prominent lemma nerves and hairs are widespread in the *P. stricta* groups, so this is not a useful distinction. I found the lemma tips to vary a great deal in the material I examined and did not persist with it as an informative character. The bidentate (as opposed to entire or bifid) palea was not a condition that either I nor Neville Walsh could reliably identify. As a result, I suggest that, as Table 4 indicates, the values represented for 'Species A' do not differentiate it from *P. stricta.*

If further study of *Puccinellia stricta* were to be carried out, then the WA collections would be the best place to start because they are geographically isolated from the eastern collections, and Figure 5 indicates that (a) they all fall towards one end of the first coordinate, and (b) they show the widest divergence on the second coordinate.

To identify environmental factors that correlate with this wide range of morphological variation, a good starting point would be the floristic survey of the wetlands of the wheatbelt region by Lyons *et al.* (2004). They found *P. stricta* (the study was done before *P. longior* was identified as a separate

species) in just one out of 22 types of species assemblage, and that species assemblage occurred in eight out of 39 site groupings identified amongst 913 field sampling sites from throughout the wheatbelt. The *P. stricta* species assemblage was widespread, largely halophyte-dominated, and characteristic of the margins of saline wetlands and disturbed areas. Their statistical model identified soil pH and gypsum content, local elevation, winter cold and amount of summer rain as significant predictors of the species assemblage's occurrence. However, *P. stricta* was rarely more than a minor component of the vegetation and most of the populations consisted of annuals.

Plant size variations

The WA species of *Puccinellia* reflect the most likely causes of the size variations that we see in *P. stricta* right across Australasia. *P. vassica* plants are generally at the large end of the scale for the genus, and they come from the outer edges of marine salt marsh where soil moisture is perennially high and the plants have deep roots. *P. longior* plants are also on the large side, and they also occur in areas that are seasonally well watered. However, *P. stricta* exhibits the greatest range in plant size and comes exclusively from inland salt lakes or salt-affected lowlands that regularly dry out in summer. Their habitat is thus consistently subjected to severe water deficit and corresponding high salt concentrations. I infer that the stunted habits are simply the result of these environmental factors as demonstrated experimentally for other *Puccinellia* species by Davis (1983), and have no taxonomic significance. Growth trials under different salinity regimes would provide evidence that could be useful to test this notion.

Relationship between WA collections of *P. stricta* and other species

To test the possibility that the WA collections of *P. stricta* might be similar to either an introduced species, or to a sibling species of *P. stricta* in New Zealand, a multivariate analysis was carried out including relevant data for *P. walkeri*, the closest of the NZ endemic taxa to *P. stricta,* together with a variety of other native and exotic species for which we have comparable data (*P. vassica, P. longior, P. perlaxa, P. harcusia, P. ciliata, P. gigantea, P. grossheimiana, P. distans, P. fasciculata, P. maritima*).

The PCoA analysis placed *P. walkeri* at the same end of coordinate 1 as the *P. stricta* group, but both cluster methods grouped *P. walkeri* most closely with *P. maritima*, a marine saltmarsh species from the northern hemisphere that does not occur in Australia, so it is clearly distinct from *P. stricta.* Both cluster methods put the WA collections in the *P. stricta* group. In this group, the Tasmanian and New Zealand collections were the most similar; they were then joined by the southeastern Australian mainland group, with the WA group joining last.

Variation in *Puccinellia ciliata*

Bor (1968) distinguished *P. ciliata* from its nearest relative *P. gigantea* with "the lemma is completely glabrous on the dorsal surface while the keels of the palea are long ciliate in the lower half". Tan (1985) contradicted both these claims after re-examining types and other material determined by Bor. The isotype of *P. ciliata* at PERTH (00985422) is consistent with Tan's criticism and even has some palea keels glabrous in the lower half. This suggests that *P. ciliata* may not be a separate taxon. Tan retained *P. ciliata* however by saying that glume lengths were distinctly different, citing a range

of 0.8–1.2 mm for the lower and 1.5-2 mm for the upper glume in *P. gigantea* and 1.5–2 mm and 3–3.5 mm for *P. ciliata*. In our PERTH material the upper and lower glume length ranges for *P. ciliata* are 1.2–2.0 mm and 2.0–3.5 mm respectively so the two ranges are contiguous.

To examine the difference between *P. ciliata* and *P. gigantea* more comprehensively I carried out a Principal Coordinates Analysis on just the spikelet data for our PERTH collections of these species together with the average values from Tan (1985). The points formed a complete continuum from the average values cited by Tan for *P. gigantea* through to the average values for *P. ciliata* and beyond. And there was no clear difference between the material from Australia and that from Turkey, except in the number of florets per spikelet.

The number of florets per spikelet for *P. ciliata* quoted by Tan was 8–11, but all our material had consistently fewer, ranging as low as 4–5. Tan noted a tendency towards lower values in cultivated specimens, and the Australian material has all been selected for agricultural use. I noted earlier that considerable variation in this character can occur just within a single panicle in *P. stricta*, so I am reluctant to place any taxonomic significance upon it here.

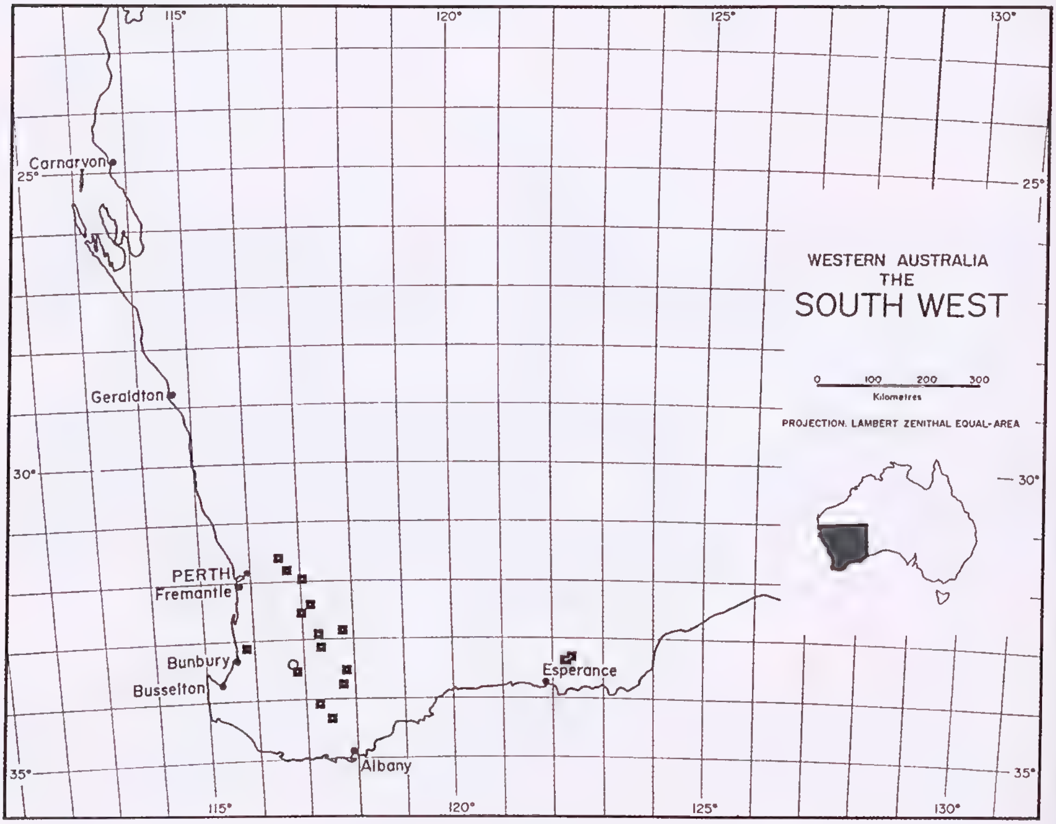

Figure 6. Distribution of exotic species of *Puccinellia* in Western Australia. *P. ciliata* ■ *P. gigantea* ○

Discussion

Despite the worldwide difficulty of identifying species of *Puccinellia,* most of the specimens in our collection have now been assigned to existing or new species categories. Amongst those collected in Western Australia we now have recorded the native *P. stricta*, and the new species *P. longior* and *P. vassica*, and the introduced *P. ciliata* and *P. gigantea.*

The native species *P. stricta* appears to be reasonably well established and not in need of special consideration for conservation. The new species *P. longior* is represented by only 11 collections. It may be marginally salt-tolerant and thus vulnerable to the increasing salinity in this area and may need to be considered for conservation status.

In stark contrast, *P. vassica* seems to be on the verge of extinction. It had not been collected for 70 years, despite an increased effort in recent years to survey the state's land edges (the SWALE project http://florabase.dec.wa.gov.au/swale/). A SWALE transect was located within a few metres of where *P. vassica* was found in the Bunbury mangrove reserve, yet missed it. It is almost certainly now extinct where first collected in the Vasse-Wonnerup salt marshes near Busselton, because that habitat no longer exists. In the Leschenault reservations there are only small numbers of plants, widely dispersed, and weed invasion is imminent, especially in the mangrove reserve at Bunbury.

Furthermore, *P. vassica* has no apparent competitive defence against invading weeds. While it appears to be a perennial species, the culms die back almost completely each year and only the roots seem to keep a strong and deep hold on its place. It also seems to set few viable seeds as all three sites had only scattered individual plants and nowhere was it in pure stands such as those in which *P. ciliata* is able to establish in similar habitats.

In contrast, the competing perennial grass species in much of its distribution is the native *Sporobolus virginicus* which produces vigorous and enduring stoloniferous growth that can entirely take over suitable habitats. Another competitor is the native sea rush *Juncus kraussii* which keeps a strong hold on ground that it wins by maintaining tall stands of perennially durable tough stems that propagate vegetatively via rhizomes. Amongst the weed competitors, rye grasses (*Lolium* spp.) are prolific seeders and stoloniferous, thus being able to reach in from the non-saline edges into the outer high tide influence zone where *P. vassica* lives.

Amongst the vouchers of material imported into Western Australia by Malcolm and others. I have identified *P. ciliata, P. distans, P. gigantea*, and *P. grossheimiana*. Amongst these it appears that *P. distans* and *P. grossheimiana* have not become naturalized in WA and only one specimen of *P. gigantea* has been collected in the field. It appears that *P. ciliata* has adapted well to WA conditions and is naturalised in the wetter parts of the agricultural region, having spread from initial planting sites to adjacent farmland and roadsides.

Regarding usefulness for reclamation of salt-degraded land *P. ciliata, P. gigantea* and *P. longior* produce the most foliage mass per plant, and *P. ciliata* shows no sign of becoming a nuisance weed. *P. longior* may also be more persistent than the exotic species. In October 2003, Clive Malcolm sent me seven collections of *Puccinellia* from sites that he had planted 30 or 40 years ealier with *P. ciliata* but in only one of these had the latter survived and in all the other 6 sites the specimens were *P. longior*. Landowners wishing to promote native species use could cultivate *P. longior* and develop a seed supply to encourage others to follow suit.

Formal Taxonomy

Species descriptions and an interactive key to the Australian species will soon become available on the FloraBase website: http://florabase.dec.wa.gov.au/ (WA Herbarium 1998–).

Key to *Puccinellia* Species in Western Australia

1. Anther colour rusty brown, 1.1–1.7mm long; ligules 3–5mm long .... **P. longior**

1. Anther colour creamy white, sometimes tinged purple, various lengths; if brownish tinged then <1 mm long and ligules < 3 mm long 2

2. Panicle exserted from flag leaf sheath at anthesis, branches spreading, most being bare in the lower part 3

2. Panicle usually partially enclosed by leaf sheath at anthesis, branches mostly contracted (may spread later), spikelets distributed evenly on branches or crowded near the base 4

3. Glumes subequal, the lower more than half as long as the upper; upper glume 1.9–3.5 mm long; lower glume 1.2–2.3 mm long ....***P. ciliata**

3. Glumes unequal, the lower being little over half as long as the upper; upper glume 1.2–2 mm long; lower glume 0.8–1.2 mm long..................................***P. gigantea**

4. Spikelets crowded towards base of glabrous panicle branches; lemmas and paleas glabrous in lower half; callus glabrous; ligules 2.5–5 mm long (southwest W.A. marine salt marshes) .... **P. vassica**

4. Spikelets ±evenly distributed along scabridulous panicle branches; lemmas and paleas usually with dorsal hairs in lower half; callus with some hairs; ligules 1–3 mm long (widespread in saline soils in southwest agricultural regions of W.A. and across southern Australasia) .... **P. stricta**

1. Puccinellia stricta (Hook.f.) C.H.Blom, *Acta Horti Gothob.* 5: 89 (1930). – *Glyceria stricta* Hook.f., *Fl. Nov.-Zel.* 1: 304 (1853); *Atropis stricta* (Hook.f.) Hack., *in:* T.F.Cheeseman, *Man. New Zealand Fl.* 914 (1906). *Type:* Launceston, Tas., 24 Dec. 1844, *R.C.Gunn* 1463 (*lecto:* K (high resolution image seen), *fide* H.H. Allan & P. Jansen, *Trans. & Proc. Roy. Soc. New Zealand* 69: 265 (1939); *isolecto:* HO, seen).

Poa syrtica F.Muell., *Trans. & Proc. Victorian Inst. Advancem. Sci.* 45 (1855); *Festuca syrtica* (F.Muell.) F.Muell., *Fragm.* 8: 130 (1873); *Panicularia syrtica* (F.Muell.) Kuntze, *Revis. Gen. Pl.* 2: 782 (1891). *Type:* 'Sandy shores of Lefevre Peninsula [St Vincent's and Spencer's Gulf, S.A.]', 'In grassy pastures at the end of Holdfast Bay' Dec. 16, 1847 (MEL, two sheets, three labels, seen).

Glyceria tenuispica Steud. *Synopsis Plantarum Graminearum* Part 1:285 (1855). *Type: Drummond* collection V no. 347 (*iso:* K, high resolution image seen).

(a) Western Australian (WA) collections character summary:

Root system caespitose; duration annual; *culm* height 85–270 mm; *leaf* blade length 35–135 mm; leaf blade involute, or more or less flat; erect, or flexuose; width 0.5–1.5 mm; ligule length 1–2.3 mm. *Panicle* shape contracted at flowering time (may spread later); panicle length 50–100 mm; panicle branch surface smooth (or almost so), or scabridulous; panicle enclosed by flag leaf, or exserted above flag leaf; number of lower panicle branches per node 3–5; spikelets on lower panicle branches crowded near the base of lateral branches, or evenly spread; spikelets per node (mean of lower two nodes) 9–25. *Spikelets* not overlapping one another on panicle branches, or overlapping one another on panicle branches; minimum peduncle length 0.5–1.5 mm; maximum peduncle length 4–10 mm; maximum branch length 16–36 mm. Spikelet length 4.5–10 mm; number of florets per spikelet 5–10. Lower glume length 1–2 mm; upper glume length 1.5–3 mm; glume tips entire. *Lemma* tip tapering; lemma length 2–3.5 mm; lemma nerves obscure, or prominent; lemma midnerve not extending to the margin; lemma indumentum of sparse hairs near base, or ciliate. *Palea* length 1.9–2.8 mm; scabrous or ciliate in lower half. Callus ciliate. *Anther* length 0.5–0.9 mm; colour creamy white. (Figure 7)

Distribution and phenology. A minor component of halophyte communities on the outer margins of inland saline lakes, river and estuary margins throughout the WA wheatbelt from Utcha Spring north of Hutt Lagoon in the north, to the Fitzgerald River on the south east coast. Also occasionally in salinised pasture and shrubland. Flowers Sept.–Nov. (Figure 3)

(b) Other Australasian (SEANZ) collections character summary:

Root system caespitose; duration annual, or perennial; *culm* height 140–750 mm; *leaf* blade length 50–180 mm; leaf blade involute; erect, or flexuose; width 0.5–1.6 mm; ligule length 0.9–3 mm. *Panicle* shape contracted at flowering time (may spread later); panicle length 65–310 mm; panicle branch surface scabridulous; panicle enclosed by flag leaf; number of lower panicle branches per node 3–9; spikelet distribution on lower panicle branches evenly spread; spikelets per node (mean of lower two nodes) 5–75. *Spikelets* not overlapping one another on panicle branches, or overlapping one another on panicle branches; minimum peduncle length 1–5 mm; maximum peduncle length 5–30 mm; maximum branch length 20–100 mm. Spikelet length 5–10 mm; number of florets per spikelet 4–9. Lower glume length 1–3 mm; upper glume length 2–3.8 mm; glume tips entire. *Lemma* tip tapering; lemma length 2.3–3.7 mm; lemma nerves obscure, or prominent; lemma midnerve not extending to the margin; lemma glabrous, or with sparse hairs near base. *Palea* length 2.1–3.4 mm; scabrous or ciliate in lower half. Callus ciliate. *Anther* length 0.5–0.9 mm; colour creamy white. (Figure 7)

Distribution and phenology. Margins of saline lakes, salt-affected lowlands, marine saltmarsh and estuarine salt flats across southern Australasia. Flowers Sept.–Feb. (Figure 3)

Illustrations. J.P.Jessop & H.R.Toelken (eds), *Fl. S. Australia* 4th edn, 4: 1902, fig. 866A (1986); N.G.Walsh *in* N.G.Walsh & T.J.Entwisle (eds), *Fl. Victoria* 2: 413, fig. 82h–j (1994); W.M.Curtis & D.I.Morris, *Student's Fl. Tasmania* 4B: 205, fig. 60 (1994). Note: the illustration labelled *P. stricta* in Gardner's *Flora of Western Australia* Vol.1, Pt.1, (1952) Plate XXVIIIB is now *P. vassica* A.R.Williams (see this text).

Notes. Recent collections during the wheatbelt survey that focused on salt lake and saline habitats have greatly increased the size of our collection, suggesting that this habitat and species is under-collected in regard to its proportionate representation in PERTH holdings. The common name for this species is 'Australian Saltmarsh Grass'.

(a) Selected specimens examined (all PERTH). WESTERN AUSTRALIA: 17.45 km due SE of Kau Rocks, *M.A. Burgman & C. Layman* MAB 3419, 2 Sep. 1984; R.G. Clarke's property, Lake Grace, *G.H. Burvill s.n.*, 10 Oct. 1946; Gairdner River, Jerramungup, *C.A. Gardner s.n.*, Aug. 1939; 2.5 km NE of the SE of Pinjarrega Lake (Pinjarrega Nature Reserve), *S. Hamilton-Brown* RG 30, 20 Sep.2000; On W side of Grey Road, Utcha Spring Nature Reserve, c. 2.5 km N of Hutt Lagoon, *G.J. Keighery & N. Gibson* 5212, 28 Oct. 1998; Unnamed salt lake SE of Ellen Peak, Stirling Range, *G.J. Keighery* 7035, 28 Oct.1983; Pallinup River, near Greaves Hill, *G.J. Keighery* 8749, 1 Nov. 1986; Northern shore of Lake Dumbleyung, *M.N. Lyons* 2700, 27 Oct. 2000; Eastern shore of Lake Coyrecup, 25 km E of Katanning, *M.N. Lyons* 2702, 12 Oct. 1999; NE shore of Lake Bryde. 18 km SW of Newdegate, *M.N. Lyons* 2705, 11 Oct. 1999; E shore of Lake Ronnerup, Lake King Nature Reserve, *M.N. Lyons* 2707, 9 Oct. 1999; Claypan on W side of Koorda–Wyalkatchem Rd, 1.0 km S of Wyalkatchem North Rd., PERTH 06113273, *M.N. Lyons* 2711, 2 Dec. 1998 and PERTH 06113109, *M.N. Lyons,* 2713, 10 Sep. 2000; Yellilup Swamp, *c.* 37.5 km W of Bremer Bay. , *M.N. Lyons* 2722, 20 Nov. 1999; Yarra Yarra Lake, *c.* 4.5 km S of Three Springs. , *M.N. Lyons* 2725, 2 Oct. 2000; Tardun Christian Brothers College Melaleuca Swamp, *M.N. Lyons* 2726, 26 Sep. 2000; 1.5 km SW of Israelite Hill, *c.* 180 km E of Esperance, *K.R. Newbey* 7982, 9 Nov. 1980; Mouth of Fitzgerald River (Fitzgerald River National Park), *K.R. Newbey* 10997, 21 Oct. 1985; 21 km NE of Scaddan on Lignite Road, *P. van der Moezel,* PGV 474, 12 Sep. 1984; Seagroatt Nature Reserve, *S. Chalwell* SC 17, 14 Oct. 2003.

(b) Selected specimens examined. (non-WA locations): SOUTH AUSTRALIA: Knoxville, eastern suburb of Adelaide, on alkaline soil, 14 Oct. 1928, *J.B. Cleland s.n.* (MEL); Saline swamps near the Grange, about 9km west of Adelaide, 15 Sep. 1962, *D.N. Kraehenbuehl* 645 (AD); Beside Washpool, Sellicks Beach, 15 Oct. 1995, *A.G. Spooner* 15556 (AD). VICTORIA: Wimmera Study Area Sector A, sub-block 3C, 12 Nov. 1986, *A.C. Beauglehole* ACB 86655 (MEL); Wimmera Study Area Sector F, sub-block 28D, 17 Sep. 1984, *A.C. Beauglehole* ACB 84656 (MEL); Clay pans, Lowan, *F.M. Reader s.n.* Nov. 1896 (PERTH). TASMANIA: North East Isle, Kent Group, 10 Dec. 1982, *N.P. Brothers s.n.* (HO); *Sarcocornia – Disphyma* heathland, grazed area of saltmarsh, 13 Nov. 2000, *A.M. Buchanan* 15789 (HO); Brown's River, Kingston, 23 Dec. 1944, *W.M. Curtis s.n.* (HO); Saline mud, edge of Township Lagoon, Tunbridge, 7 Nov. 1978, *D.I. Morris* 7820 (HO); Wasteland next to council refuse disposal area, Township Lagoon, Tunbridge, 9 Nov. 1983, *A. Moscal* 3918 (HO); Glen Morey Saltpan, near Tunbridge, 8 Nov. 1984, *A. Moscal* 8783 (HO). NEW ZEALAND: Saltwater Creek, North Canterbury, 4 Dec. 1979, *E. Edgar & B.A. Matthews s.n.* (CHR); Port Nicholson, North Island, *T. Kirk s.n.* (CHR); Quail Island, eastern end, Banks Peninsula, 27 Dec. 1983, *H.D. Wilson* BP265 (CHR); Saline flats near Heathcote River, Christchurch, 16 Dec. 1957, *A.J. Healy* 57/466 (CHR); At rear of beach, Puponga, N.W. Nelson, Dec. 1978, *A.P. Druce s.n.* (CHR); Saline flats, Saltwater Creek, N. Canterbury, 8 Dec. 1954, *A.J. Healy* 54/538 (CHR); Margin of coastal lagoon, near Ocean Beach, Southland, 28 Feb. 1969, *A.J. Healy* 69/248 (CHR); Coastal rock ledges on steep-sided island close to coastal cliffs of mainland, north of Flea Bay, Banks Peninsula, 4 Dec. 1984, *H.D. Wilson* BP480 (CHR).

Figure 7. *Puccinellia stricta* in Western Australia. A – normal plant with contracted panicle; B – dwarf plant; C – exserted panicle with short branches and few spikelets; D – plant with expanded panicle; E – spikelets; F – anthers; G – lodicules; H – normal lemmas with few small hairs near base and on callus; I – ciliate lemmas; J – ligule; K – normal palea with keel hairs; L – palea split and flattened to show lower extent of keel hairs. Digital images from *K.R. Newbey* 10997 (A, E–H, J–K); *M.N. Lyons* 2701 (B); *G.J. Keighery & N. Gibson* 5212 (C); *M.N. Lyons* 2726 (D, I, L) (PERTH).

2. Puccinellia longior A.R.Williams, *sp. nov.*

Affinis *P. stricta* sed plantae saepe ampliatas; ligula 3–5 mm longam; antherae lineares, ferrugineas, 1.1–1.7 mm longas; distributio restrictam lacusides salini paludes margineum et campi salini continentalis inferior austro-occidentalis Australia Occidentalis.

Typus: Lake on S side of Warren Rd, 7.5 km SW on Warren Rd of intersection with Coomelberrup Rd, *c.* 16.5 km NE of Katanning, 33° 36' 35.400" S, 117° 42' 47.000" E, 24 October 1999, *M.N. Lyons* 2710 (*holo:* PERTH 06113168; *iso:* AD, CANB).

Root system caespitose; duration annual, or perennial; *culm* height 250–750 mm; *leaf* blade length 75–350 mm; leaf blade involute, or more or less flat; erect, or flexuose; width 0.5–1.5 mm; ligule length 3.3–4.8 mm. *Panicle* shape contracted at flowering time (may spread later); panicle length 85–290 mm; panicle branch surface scabridulous; panicle enclosed by flag leaf; number of lower panicle branches per node 2–5; spikelet distribution on lower panicle branches evenly spread; spikelets per node (mean of lower two nodes) 8–137. *Spikelets* not overlapping one another on panicle branches, or overlapping one another on panicle branches; minimum peduncle length 0.5–6 mm; maximum peduncle length 3–37 mm; maximum branch length 11–120 mm. Spikelet length 4–10 mm; number of florets per spikelet 3–9. Lower glume length 1.2–2.2 mm; upper glume length 2–3.3 mm; glume tips entire. *Lemma* tip tapering; lemma length 2.4–3.7 mm; lemma nerves obscure; lemma midnerve not extending to the margin; lemma indumentum glabrous, or sparse hairs near base. *Palea* length 2.3–3.4 mm; indumentum scabrous or ciliate in lower half. Callus hairs ciliate. *Anther* length 1.1–1.7 mm; colour rusty brown. (Figure 8)

Distribution and phenology. Native, WA, SA. Recorded in WA only from the outer margins of inland saline lakes and salt-affected areas within the southern wheatbelt, on the transition from rejuvenated drainage on the coast to ancient drainage inland. The single record from South Australia is from the outer margins of a salt lake in the south east (the wetter area) of the state. Its presence could perhaps be anticipated in south-western Victoria. Flowers Sept.–Nov. (Figures 2,3)

Specimens examined (all PERTH). WESTERN AUSTRALIA: 23 km NW of Mt Barker, Wamballup Nature Reserve, *A.R. Annels* ARA 3786, 22 Sep. 1993; N shore of Lake Dumbleyung, *M.N. Lyons* 2706, 26 Oct. 2000; Twonkwilling Pool, on Police Pools Rd 4.5 km SE of Katanning, *M.N. Lyons* 2717, 12 Sep. 1999; Little White Lake, *c.* 19 km ENE of Highbury, Arthur River Nature Reserve, *M.N. Lyons* 2708, 9 Nov. 2000; Parkeyearing Lake, 5 km S of Wagin, *M.N. Lyons* 2714, 26 Oct. 2000; Yoting Town Reserve, 18.5 km E Quairading, *B.G. Muir* 219, 6 Sep. 1977; Aldersyde, R. Sudholz property, Brookton, *C.V. Malcolm* CVM 82, 28 Sep. 2003; Quairading, Ivan Lee property 'Bulyee', *C.V. Malcolm* CVM 83, 30 Sep. 2003; Mt Kokeby, T. Ridgeway property, *C.V. Malcolm* CVM 84, 29 Sep. 2003; Quairading, Hinkley property, *C.V. Malcolm* CVM 92, 30 Sep. 2003; SOUTH AUSTRALIA: Gum Lagoon Conservation Park, 36° 17' 13" S, 140° 11' 18" E, *R.J. Davies* GL1255, 16 Nov. 1996 (AD).

Etymology. The epithet *longior* is derived from Latin and refers to the long anthers and long ligules.

Affinities. P. longior appears to be most closely related to *P. stricta*, but the long rusty colored anthers are distinctive. I considered the possibility of it being a hybrid with *P. ciliata*, which grows across a similar range, but the anthers on the latter are white, often with a purple tinge, and are quite distinct. One specimen of *P. stricta* from Island Bay in New Zealand (CHR25440, *A.J. Healy s.n.*, 9 Nov. 1940) had small (0.6 mm) rusty colored but somewhat immature anthers. This suggested to me that

Figure 8. *Puccinellia longior*. A – single flowering culm; B – panicle; C – spikelet; D – anthers; E – lemmas with callus and rachilla segment; F – palea; G – ligule. Digital images from *M.N. Lyons* 2710 (A, C, G); *M.N. Lyons* 2714 (B); *M.N. Lyons* 2706 (D, E–F) (PERTH).

perhaps this character was in the ancestral gene pool of the native rather than the exotic species and had been retained until it became expressed here in *P. longior.* All but one of our collections carried no fruiting-stage spikelets, but that one specimen (*B.G. Muir* 219) had two old panicle branches on it. Amongst the few remaining spikelet fragments, I found two mature seeds (one an empty, insect-eaten half shell, and the other a fungus-riddled whole that disintegrated when I touched it), so the taxon is fertile, which eliminates the sterile-hybrid (but not the fertile-hybrid) possibility.

3. Puccinellia vassica A.R.Williams, *sp. nov.*

Affinis *P. stricta* var. *stricta* sed spiculae aggregata in pedunculi brevis glabri, palea pro parte maxima glabra, et habito palus salsa ora austro-occidentali Australia Occidentalis differt.

Typus: coastal salt marsh, Leschenault Inlet, 16 November 2005, *A.R. Williams* 878 (*holo:* PERTH 07576021, *iso:* AD, CANB).

Illustration. C.A.Gardner, *Flora of Western Australia* Vol.1, Pt.1. Plate XXVIIIB (1952) as *P. stricta.*

Root system caespitose; duration annual, or perennial; *culm* height 410–545 mm; *leaf* blade length 120–215 mm; leaf blade involute; erect; width 0.8–2.5 mm; ligule length 2.5–5 mm. *Panicle* shape contracted at flowering time (may spread later); panicle length 150–185 mm; panicle branch surface smooth (or almost so); panicle enclosed by flag leaf, or exserted above flag leaf; number of lower panicle branches per node 2–15; spikelet distribution on lower panicle branches crowded near the base of lateral branches; spikelets per node (mean of lower two nodes) 20–75. *Spikelets* crowded together near the nodes; minimum peduncle length 1–2 mm; maximum peduncle length 3–17 mm; maximum branch length 10–70 mm. Spikelet length 6.5–10.5 mm; number of florets per spikelet 5–10. Lower glume length 1.9–2.8 mm; upper glume length 3.1–4 mm; glume tips entire. *Lemma* tip tapering; lemma length 3.1–4.5 mm; lemma nerves obscure; lemma midnerve not extending to the margin; lemma indumentum glabrous. *Palea* length 2.9–3.4 mm; indumentum glabrous in lower half. Callus hairs glabrous. *Anther* length 0.8–1 mm; colour creamy white. Figure 9

Specimens examined. WESTERN AUSTRALIA: Busselton, 1870, *A. & E. Pries s.n.* (MEL); Busselton,14 Nov. 1936, *C.A. Gardner s.n.* (PERTH); *Drummond* 219 (MEL); *Drummond s.n.* (MEL 2139536); *Drummond s.n.* (MEL 2139537); *Drummond s.n.* (MEL 2139538); Leschenault Inlet, 5 Nov. 2005, *G.J. & B.J. Keighery* 962; Bunbury, 16 Nov. 2005, *A.R. Williams* 875 (PERTH); Leschenault Inlet, 16 Nov. 2005, *A.R.Williams* 880 (PERTH).

Distribution and phenology. Native, W.A. Collected recently only from the outer margins of coastal saltmarsh in the Leschenault Inlet; collected in 1870 and 1936 from the Vasse-Wonnerup estuary near Busselton but the habitat has since been destroyed by the installation of floodgates to reduce inflow of seawater. Flowers Sept.–Nov. (Figure 3)

Conservation status. DEC Conservation Codes for Western Australian Flora: Priority One.

Etymology. The species epithet alludes to the region of first collection, the Vasse region surrounding the town of Busselton. The Vasse River was named after a French sailor who drowned there in the 18th century. The common name of this species is 'Busselton Salt Grass'. Also previously known by the phrase name *Puccinellia* sp. Busselton (*C.A. Gardner s.n.* PERTH 00477664).

Figure 9. *Puccinellia vassica*. A – whole plant; B – panicle with lots of spikelets crowded onto short branches; C – spikelet; D – anther; E – glabrous lemma and callus attached to rachilla segment; F – palea with largely glabrous margins; G – ligule. Digital images from *A.R. Williams* 878 (A, C–D, G) and Busselton, 14 Nov. 1936, *C.A. Gardner s.n.* (B, E–F) (PERTH).

4. ***Puccinellia ciliata** Bor, *Notes Roy. Bot. Gard. Edinburgh* 28: 299–300 (1968). *Type:* Cultivated at CSIRO field station, Kojonup, W. Australia from seed collected at Kahic, 12 km from Menemen, N of Izmir, near the sea, Bi Izmir, Turkey, 1951, *Miles & Donald s.n.* (*holo:* E *n.v.*; *iso:* K *n.v.*, PERTH, *fide* Tan, K., *Flora of Turkey*, 9:508, 1985).

Root system caespitose; duration perennial; *culm* height 340–700 mm; *leaf* blade length 70–135 mm; leaf blade involute, or more or less flat; erect; width 0.5–1 mm; ligule length 1–6 mm. *Panicle* shape spreading at flowering time, or spreading, some branches deflexed; panicle length 120–175 mm; panicle branch surface scabridulous; panicle exserted above flag leaf; number of lower panicle branches per node 2–10; spikelet distribution on lower panicle branches evenly spread, or mainly at the ends of long bare peduncles; spikelets per node (mean of lower two nodes) 16–70. *Spikelets* not overlapping one another on panicle branches, or overlapping one another on panicle branches; minimum peduncle length 1–8 mm; maximum peduncle length 9–22 mm; maximum branch length 48–65 mm. Spikelet length 7–12 mm; number of florets per spikelet 5–11. Lower glume length 1.2–2 mm; upper glume length 2–3.5 mm; glume tips entire. *Lemma* tip tapering; lemma length 2.5–3.5 mm; lemma nerves prominent; lemma midnerve not extending to the margin; lemma indumentum glabrous, or sparse hairs near base, or ciliate. *Palea* length 2.6–2.9 mm; indumentum scabrous or ciliate in lower half. Callus hairs ciliate. *Anther* length 1.3–2 mm; colour creamy white, or creamy white with purple tinge. (Figure 10)

Specimens examined (all PERTH). WESTERN AUSTRALIA: Dattening, 5 Nov. 1997, *G.J. Keighery* 15069; NW shore Towerrinning Lake, 3 km NW of Moodiarup, 16 Nov. 2000, *M.N. Lyons* 2704; Boomall Brook, Kauring townsite, York, 13 Sep. 1999, *C. Howell* 474; Cultivated: CSIRO Field Station, Kojonup, 26 Oct. 1966, *A. Rogers s.n.*; Boomall Brook, Kauring townsite, York, 13 Sep. 1999, *C. Howell* 471; Cultivated: Department of Agriculture Glasshouse, 4 Nov. 1964, *C.V. Malcolm s.n.*; Wittenoom Hills Rd at deep culvert N of Plowmans Rd, 2 June 1999, *C.D. Turley* 7/699; Harvey, Oct. 1970, *J. Clarke s.n.*; Broomehill, Aug. 1970, *M. Coffey s.n.*; Crawley, 1971, *A.J. Paganon* 24; Wooroloo near El Caballo Blanco, E of Bodguero Way, 11 Dec. 1998, *U. Bell* 57; E side Toolibin Lake, 18 Nov. 1998, *A. Baxter & T. Macfarlane* AB 40; 3.1 km SE of Spencers Brook Rd on Mokine Rd, *c.* 13 km SW of Northam, 2 Nov. 1996, *B.J. Lepschi & T.R. Lally* BJL 3158. TURKEY: Turkey – 10 km from junction with Ankara Rd, 19 July 1967, *C.V. Malcolm* 161; Turkey – 41 km S of Igdir on road to Agri, 25 July 1967, *C.V. Malcolm* 176; 10 km from junction with Ankara Rd on Aksanay Rd, 19 July 1967, *C.V. Malcolm* 161(3); Turkey – 11 km W of Van on road to Tatvan, 28 July 1967, *C.V. Malcolm* 184; Turkey – 31 km S of Agri, 26 July 1967, *C.V. Malcolm* 181; 41 km S of Iugdir on road to Augri, Turkey, 25 Sep. 1967, *C.V. Malcolm* 177; 41 km S of Igdir on road to Agri, Turkey, 25 Sep. 1967, *C.V. Malcolm* 178.

Distribution and phenology. Introduced; native to Turkey. WA, SA, NSW, Victoria. Introduced into WA for the purpose of reclaiming salt-affected pasture land; now spread into adjoining road verges and saline lakes. Flowers Apr.–Nov. (Figure 6)

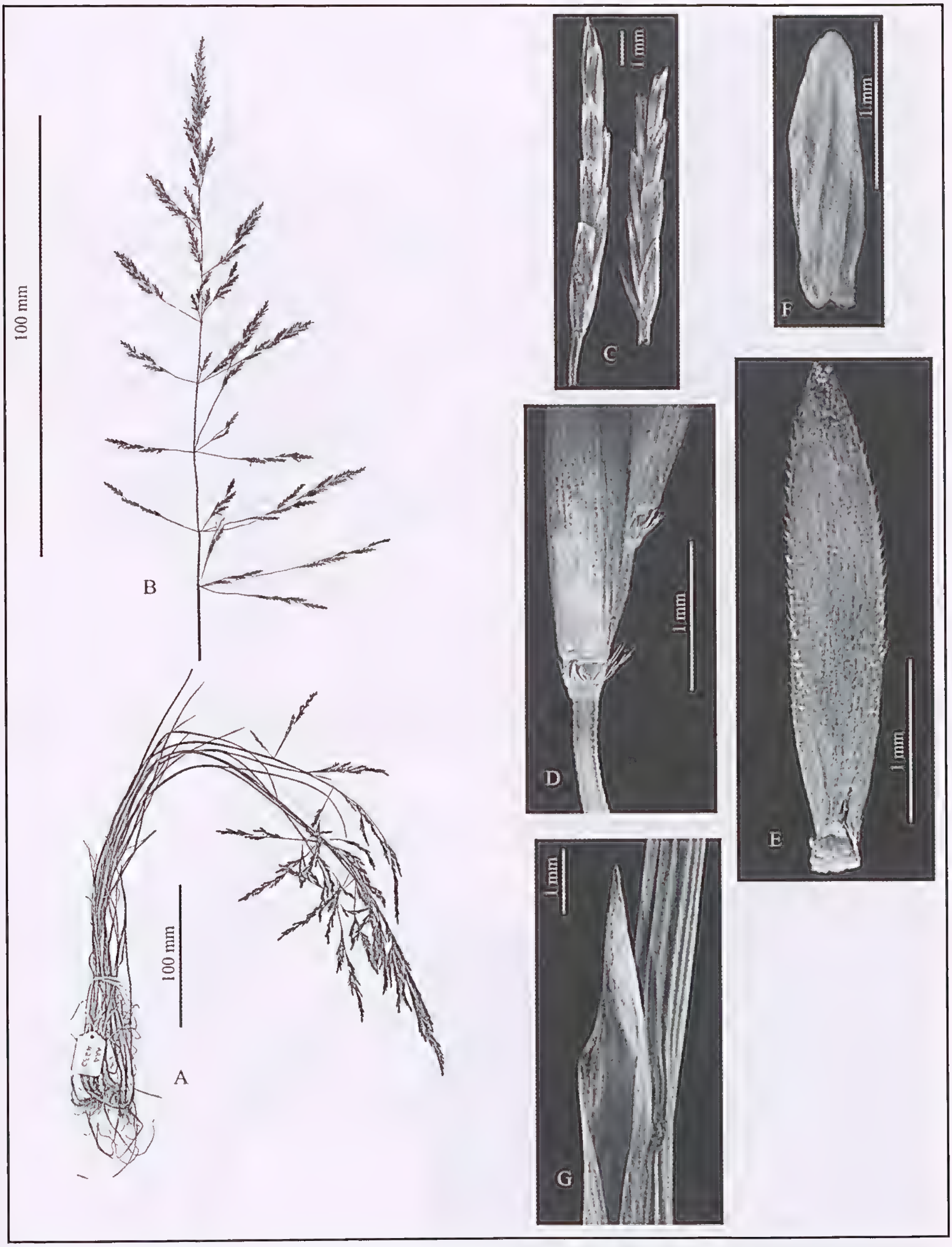

Figure 10. *Puccinellia ciliata.* A – tussock; B – panicle; C – spikelet; D – lemmas and rachilla segment; E – palea; F – anther; G – ligule. Digital images from *A.R. Annels* ARA 4232 (PERTH).

5. *Puccinellia gigantea (Grossh.) Grossh., *Fl. Kavk.* 1:114(1928) – *A. gigantea* Grossh. *in Monit. Jard. Bot. Tiflis* 46:35, t. 2 (1919). *Type:* Baku, distr. Lenkoran, Kumbashi, in pratis, 17 May 1916, A. Grossheim (*holo:* LE, *iso:* TGM).

Illustration: *Fl. URSS* 2: t. 37 f. 24 (1934), as *A. gigantea.*

Root system caespitose; duration perennial; *culm* height 440–800 mm; *leaf* blade length 65–160 mm; leaf blade involute; erect; width 0.8–1 mm; ligule length 3–4 mm. *Panicle* shape spreading at flowering time, or spreading, some branches deflexed; panicle length 150–190 mm; panicle branch surface smooth (or almost so), or scabridulous; panicle exserted above flag leaf; number of lower panicle branches per node 5–6; spikelet distribution on lower panicle branches evenly spread, or mainly at the ends of long bare peduncles; spikelets per node (mean of lower two nodes) 15–55. *Spikelets* not overlapping one another on panicle branches, or overlapping one another on panicle branches; minimum peduncle length 1–2 mm; maximum peduncle length 15–25 mm; maximum branch length 35–80 mm. Spikelet length 7–10 mm; number of florets per spikelet 6–11. Lower glume length 0.8–1.2 mm; upper glume length 1.5–2 mm; glume tips entire. *Lemma* tip tapering; lemma length 2.2–2.8 mm; lemma nerves prominent; lemma midnerve not extending to the margin; lemma indumentum glabrous, or sparse hairs near base. *Palea* length 2.5–2.9 mm; indumentum scabrous or ciliate in lower half. Callus hairs ciliate. *Anther* length 1.2–1.6 mm; colour creamy white, or creamy white with purple tinge. (Figure 11)

Specimens examined (all PERTH). WESTERN AUSTRALIA: NW shore of Towerrining Lake, 3 km NW of Moodiarup., 16 Nov. 2000, *M.N. Lyons* 2703. TURKEY: E of Kendirlik, 1 km by river, 11 July 1967, *C.V. Malcolm* 147.

Distribution and phenology. Introduced; native to Middle East and central Asia. Introduced into WA for the purpose of reclaiming salt-affected pasture land. Only one naturalized record from lower wheatbelt WA. Flowers Nov. (Figure 6)

Puccinellia perlaxa (N.G. Walsh) N.G.Walsh & A.R. Williams, *stat. nov.*

Puccinellia stricta var. *perlaxa* Walsh, N.G., *Muelleria* 7:382–384; Fig.1g,h,i p.380 (1991). *Type:* Victoria, Altona, 3 km SE of Laverton, 4 km SSW of Altona P.O., 25 Nov. 1977, *T.B. Muir* 5659 (MEL).

Notes. This species does not occur in WA. The multivariate analysis of *P. stricta* specimens from across Australasia reported in this paper included more panicle characters than had been used in previous studies and this revealed the taxon to be quite distinct from all other *P. stricta* collections. In consultation with Neville Walsh we have here elevated it to species rank.

Figure 11. *Puccinellia gigantea.* A – two whole plants; B – panicle; C – spikelets; D – lemmas with rachilla segment; E – palea; F – anther; G – ligule. Digital images from *M.N. Lyons* 2703 (PERTH).

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References

Allan, H.H. and Jansen, P. (1939). Notes on the Puccinelliae of New Zealand. *Transactions of the Royal Society of New Zealand* 69: 265–269.

Blom, C. (1930). Ullfloran vid Lackalanga. *Acta Horti Gothoburgensis*, Vol V, p.89

Bor, N. L. (1968). Two new grasses. *Notes from the Royal Botanic Gardens Edinburgh*, Vol. XXVIII, No. 3, p.299–300.

Bor, N. L. (1970). *Flora Iranica* No. 70/30. 1. *Gramineae,* p.61. (Academische Druck – u. Verlangsanstalt, Graz – Austria).

Brearley, A. (2005). *Ernest Hodgkin's Swanland: Estuaries and Coastal Lagoons of South-western Australia*, University of Western Australia Press, Crawley.

Carroll, S. (2005). *Endless Forms Most Beautiful: The new science of evo devo,* Norton, New York.

Choo, M.K., Soreng, R.J. and Davis, J.I. (1994). Phylogenetic relationships among *Puccinellia* and allied genera of Poaceae as inferred from chloroplast DNA restriction site variation. *Amer. J. Bot.* 81(1): 119–126.

Consaul, L. L. and Gillespie, L. J. (2001). A re-evaluation of species limits in Canadian Arctic Island *Puccinellia* (Poaceae): resolving key characters. *Canad. J. Bot.* 79:927–956.

Dallwitz, M.J., Paine, T.A. and Zurcher, E.J. (2000). *The DELTA System: A General System for Processing Taxonomic Descriptions*, Edition 4.12, Division of Entomology, Commonwealth Scientific and Industrial Research Organisation, Australia. http://delta-intkey.com/

Davis, J.I. (1983). Phenotypic plasticity and the selection of taxonomic characters in *Puccinellia* (Poaceae). *Syst. Bot.* 8(4): 341–353.

Davis, J.I. (1988). Genetic and environmental contributions to multivariate morphological pattern in *Puccinellia* (Poaceae). *Canad. J. Bot.* 66(12): 2436–2444.

Davis, P.H., Mill, R.R. and Tan, K. (1988). *Flora of Turkey and the East Aegean Islands*. Vol. 10:230 (Edinburgh University Press).

Edgar, E. (1996). *Puccinellia* Parl. (Gramineae: Poeae) in New Zealand. *New Zealand J. Bot.* 34(1): 17–32.

Gardner, C. A. (1952). *Flora of Western Australia – Vol. 1, Part 1, Gramineae*. (Govt. Printer, Perth).

Gibbs Russell, G.E., Watson, L., Koekemoer, M., Smook, L., Barker, N.P., Anderson, H.M. and Dallwitz, M.J. (1990). Grasses of Southern Africa, *Memoirs of the Botanical Survey of South Africa* No. 58:279–280.

Hooker, J. D. (1853). *Flora Novae-Zealandiae*, Part I, Flowering Plants, p.304. 'The Botany: The Antarctic Voyage of H.M. Discovery Ships *Erebus* and *Terror* in the Years 1839-1843'. (Lovell Reeve, London.)

Hooker, J. D. (1860). *Flora Tasmaniae*, Part III, Vol. 1, p.123. 'The Botany: The Antarctic Voyage of H.M. Discovery Ships *Erebus* and *Terror* in the Years 1839-1843'. (Lovell Reeve, London.)

Hubbard, C. E. (1984). 'Grasses. A Guide to their structure, identification, uses and distribution in the British Isles.' 3rd Ed. (Penguin Books, London)

Jacobs, S.W.L. and McClay, K.L. (1993). *Puccinellia. In:* G.J. Harden, (ed.) *Flora of New South Wales*, NSW University Press, Sydney Vol. 4:606–607.

Jessop, J.P. and Toelken, H.R. (1986). *Flora of South Australia*, South Australian Government Printer, Adelaide, Part IV: 1901–1902.

Keighery, G.J., Halse, S.A., Harvey, M.S. and McKenzie, N.L. (eds) (2004). A biodiversity survey of the Western Australian agricultural zone. *Records of the Western Australian Museum.* Supplement No. 67.

Lyons, M.N., Gibson, N., Keighery, G.J. and S.D. Lyons (2004). Wetland flora and vegetation of the Western Australian wheatbelt. *In:* Keighery, G.J. *et al.* (eds). A biodiversity survey of the Western Australian agricultural zone. *Records of the Western Australian Museum.* Supplement No. 67:39–89.

Malcolm, C. V., Clarke, A. J. and Swaan, T. C. (1984). *Plant Collections for Saltland Revegetation and Conservation*. Western Australian Department of Agriculture, Technical Bulletin No. 65.

Mueller, F.J.H.von (1872–1874). 'Fragmenta Phytographiae Australiae', Vol. VIII, p.130.

Sharp, D. and Simon, B.K. (2002). *AusGrass: Grasses of Australia.* ABRS Identification Series (CD Lucid format), CSIRO Publishing, Melbourne.

Simon, B.K. (1993). *A key to Australian grasses*. (Queensland Dept. of Primary Industries, Brisbane).

Steudel, E.G. von (1854). *Synopsis Plantarum Glumacearum* 1(3): 285.

Suomin Wang, Guiqin Zhao, Yongsheng Gao, Zhangcheng Tang and Chenglie Zhang (2004). *Puccinellia tenuiflora* exhibits stronger selectivity for K^+ over Na^+ than wheat. *Journal of Plant Nutrition* 27(10): 1841–1857.

Tan, K. (1985). *Puccinellia. In:* Davis, P.H., Mill, R.R. and Tan, K. (eds) *Flora of Turkey and the East Aegean Islands*. (Edinburgh University Press, Vol. 9:501–509).

Vegetti, C. and Anton, A.M. (2000). The Grass Inflorescence. *In:* Jacobs, S.W.L. & Everett, J. *Grasses: Systematics and Evolution*, CSIRO Publishing, Melbourne.

Walsh, N.G. (1991). New taxa in Victorian Poaceae. *Muelleria* 7:379–384.

Walsh, N.G. and Entwisle, T. J. (1994). *Flora of Victoria*, Vol. 2, *Ferns and Allied Plants, Conifers and Monocotyledons*. pp. 411–413. (Inkata Press, Melbourne).

Wang Y. *et al.* (2006). Identification of expressed sequence tags in an alkali grass (Puccinellia tenuiflora) cDNA library. *J. Plant Physiol.* (preprint, online at http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=16545489&query_hl=3&itool=pubmed_DocSum).

Western Australian Herbarium (1998–). *FloraBase — The Western Australian Flora.* Department of Environment and Conservation. http://florabase.dec.wa.gov.au/